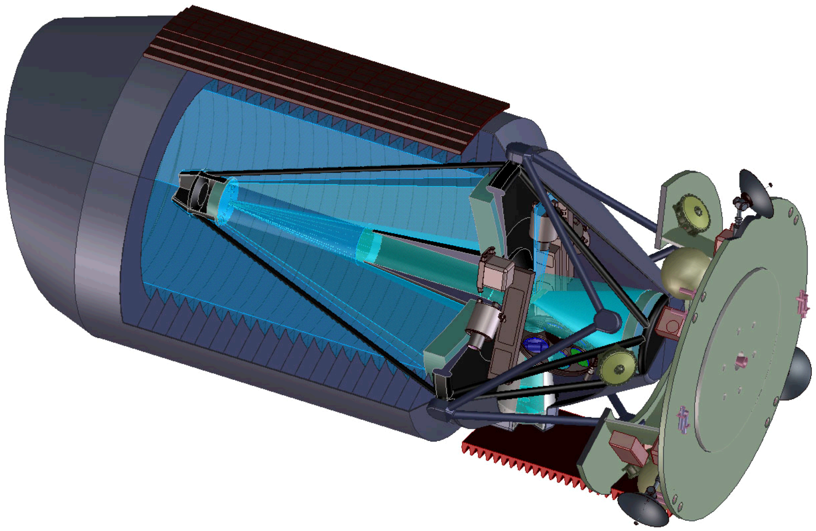
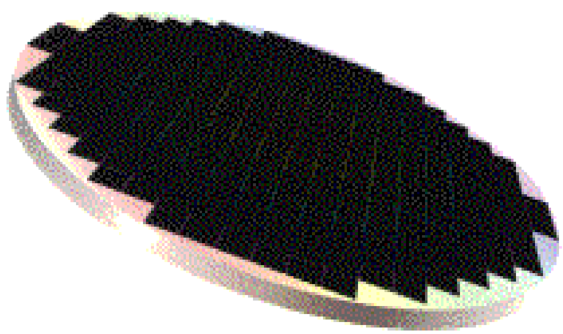
Instrumentation, Technologies, R&D
Cost & Schedule

- SuperNova /Acceleration Probe



- GigaCAM, a billion pixel CCD array



Talk Outline:

- Requirements (throughout)
- GigaCAM / CCD Technology
- Spectroscopy
- Observatory
- Orbit

[Spacecraft Talks]

- Cost (Phase I, Phase II)
- Schedule
- Management (Phase I)

Presented by: Michael Levi
March 29, 2000

Instrumentation Requirements

- Need consistent uniform data set where selection criteria can be applied and systematic sources can be analyzed and factored.
- Minimum data set criteria:

  1) discovery within 2 days of explosion (peak + 3.8 magnitude),

  2) 10 high S/N photometry points on lightcurve,

  3) lightcurve out to plateau (2.5 magnitude from peak),

  4) high quality spectrophotometry at peak,

  5) IR spectra.
- How to obtain both data quantity AND data quality?

  Batch processing techniques w/ wide field imager -- large multiplex advantage

  Mostly preprogrammed observations, fixed fields / spin filter wheel

  No Trigger ($z < 1.2$)

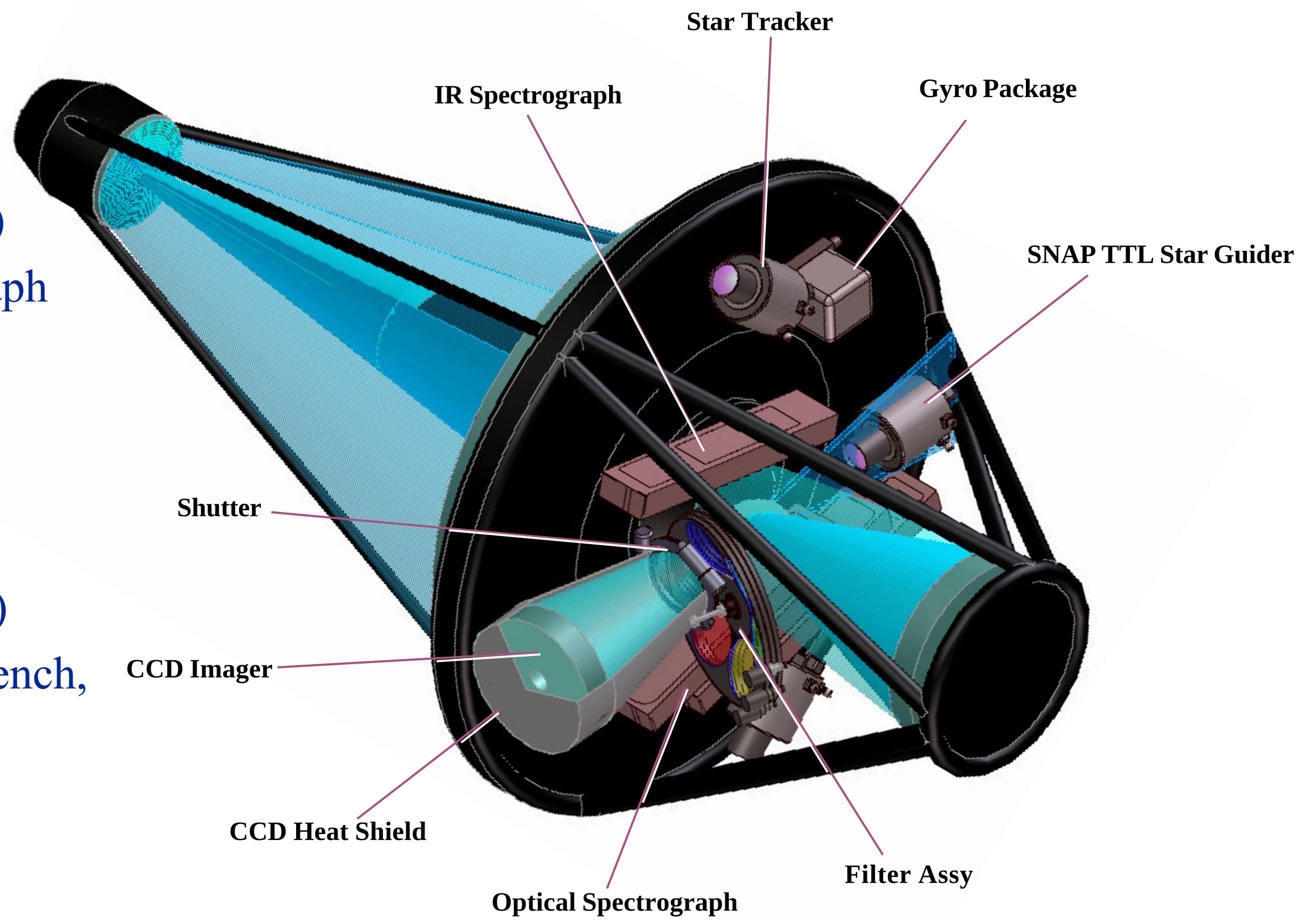
  Very simple experiment, passive, almost like accelerator expt.

  Well calibrated photometry and spectroscopy

Instrumentation Suite

Key Instruments:

1) Wide Field Imager
   (one billion pixels)
2) IR Photometer
   (small field of view)
3) 3-channel spectrograph
   350-600 nm,
   550-1000 nm,
   900-1700 nm
4) Star Guider
   (image stabilization)
5) Telescope, Optics Bench,
   Filters, Shutters



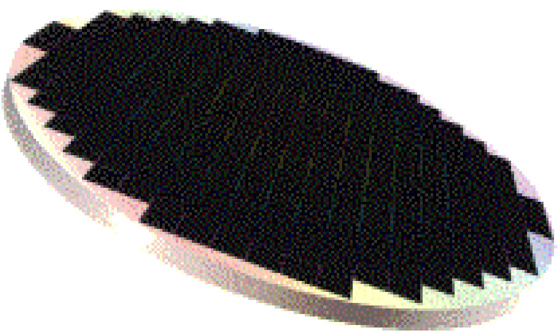
Optical Photometry Requirements

Field-of-view	1° x 1°
Plate Scale	1 pixel ~ 0.1 arcsec
Pixelization	32k x 32k CCD mosaic
Wavelength coverage	350nm - 1000nm
Detector Type	High-Resistivity P-channel CCD’s
Detector Architecture	2k x 2k, or 2k x 4k
Detector Temperature	150 K
Quantum Efficiency	65% 1000nm, 92% 900nm, >85% 400-800nm
Read Noise	4 e- @100kHz
Exposure Time	up to 1000 sec (single exposures)
Number of Frames	1 to 24
Dark Current	0.08 e-/min/pixel
Readout Time	20 sec
Limiting Magnitude	30th magnitude in Z-band
Exposure control	Mechanical shutter
Filter Wheel	15 bands (U, V, R, I, Z, & 10 special filters)

GigaCAM

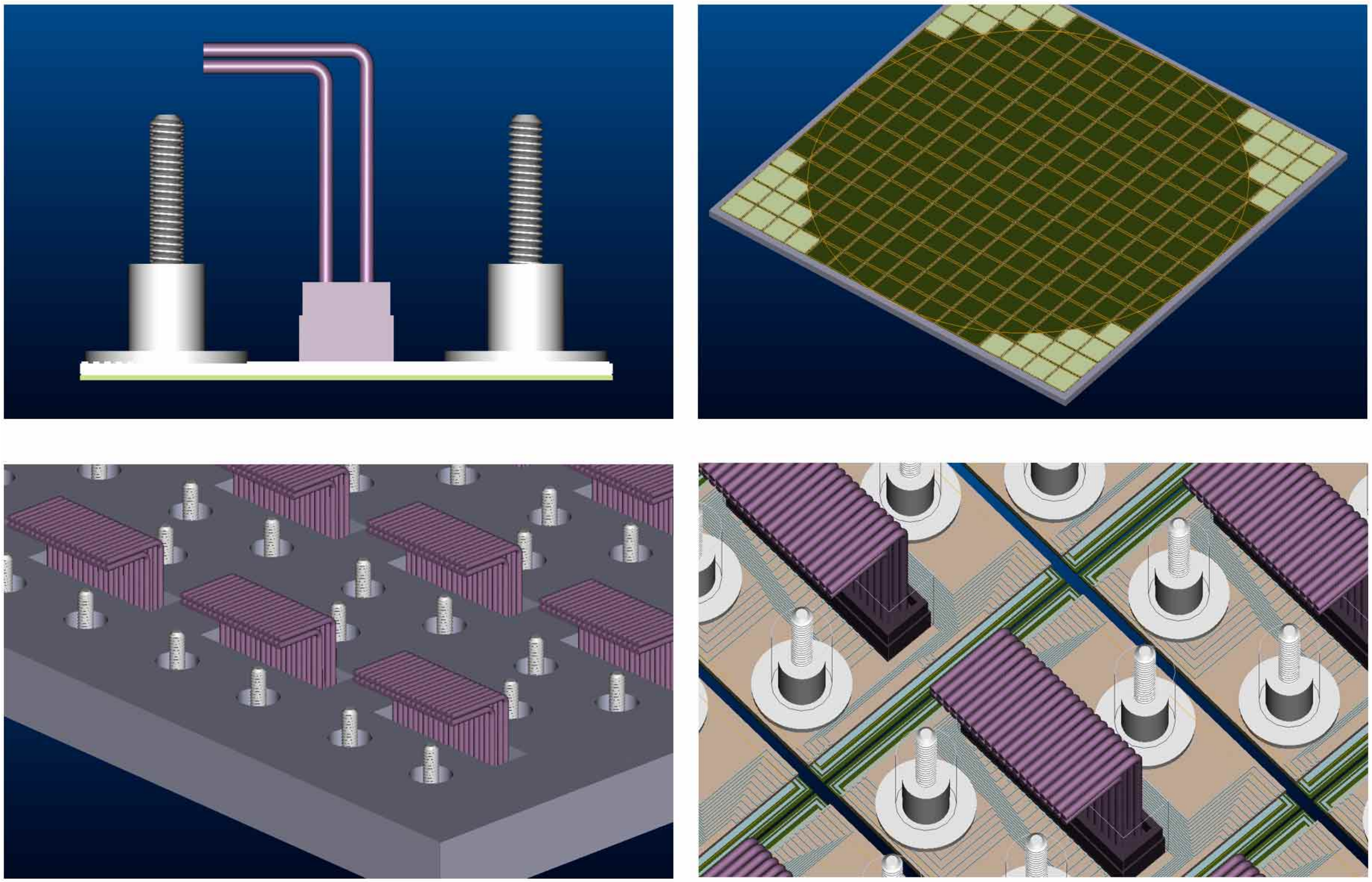
GigaCAM, a one billion pixel array

- Depending on pixel scale approximately 1 billion pixels (32k x 32k imager)
- ~200 Large format CCD detectors required
- 150K operation
- Issues: detectors, electronics, metrology
- Looks like the SLD vertex detector in Si area (0.1 - 0.2 m^2)
- Larger than SDSS camera, smaller than BaBar Vertex Detector (1 m^2)
- Collaboration has lots of experience in building very large silicon detectors and custom readout electronics including radiation hard integrated circuits (should they be necessary).

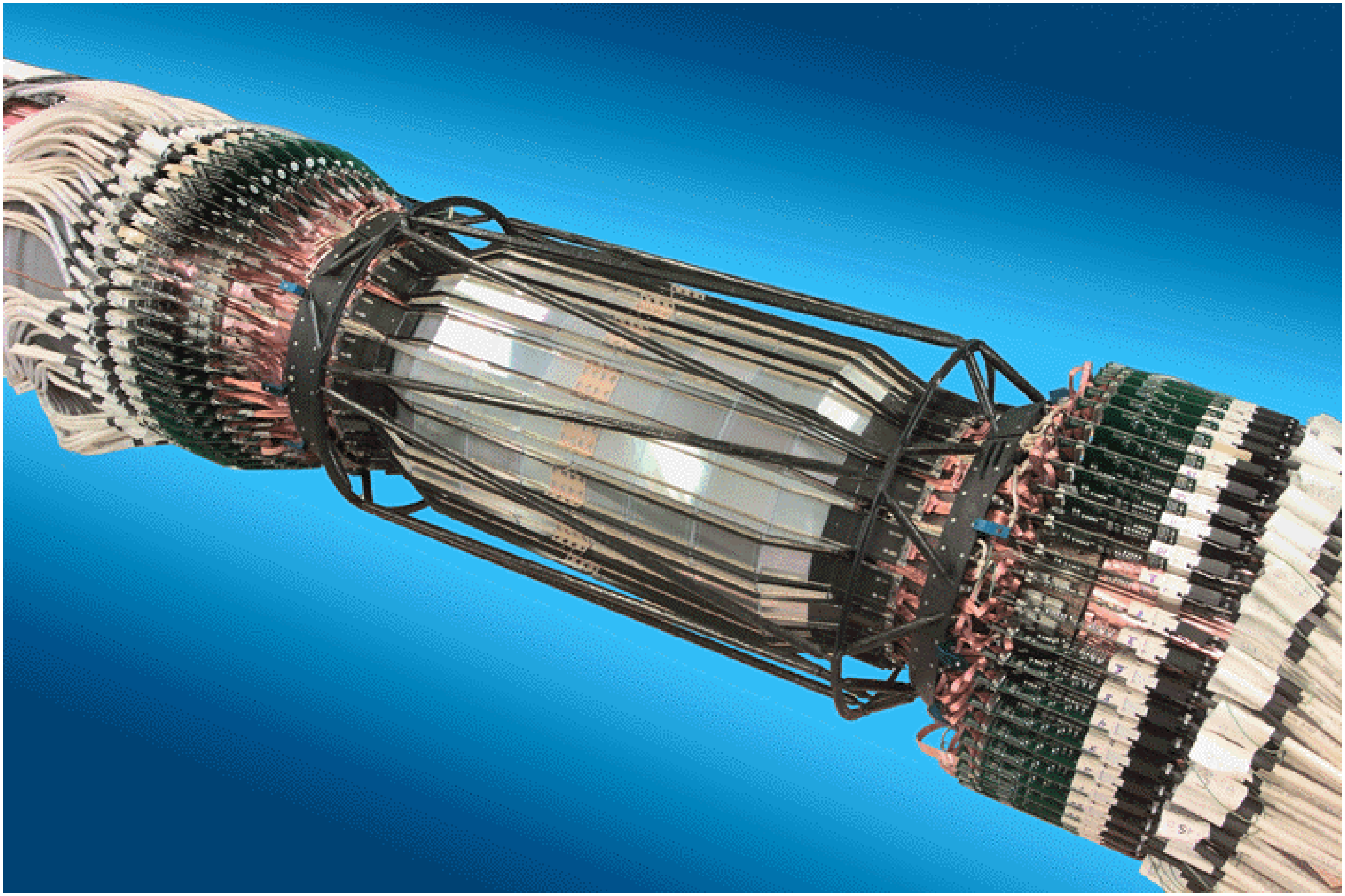


Imager Technology

32K by 32K Optical Imager Array

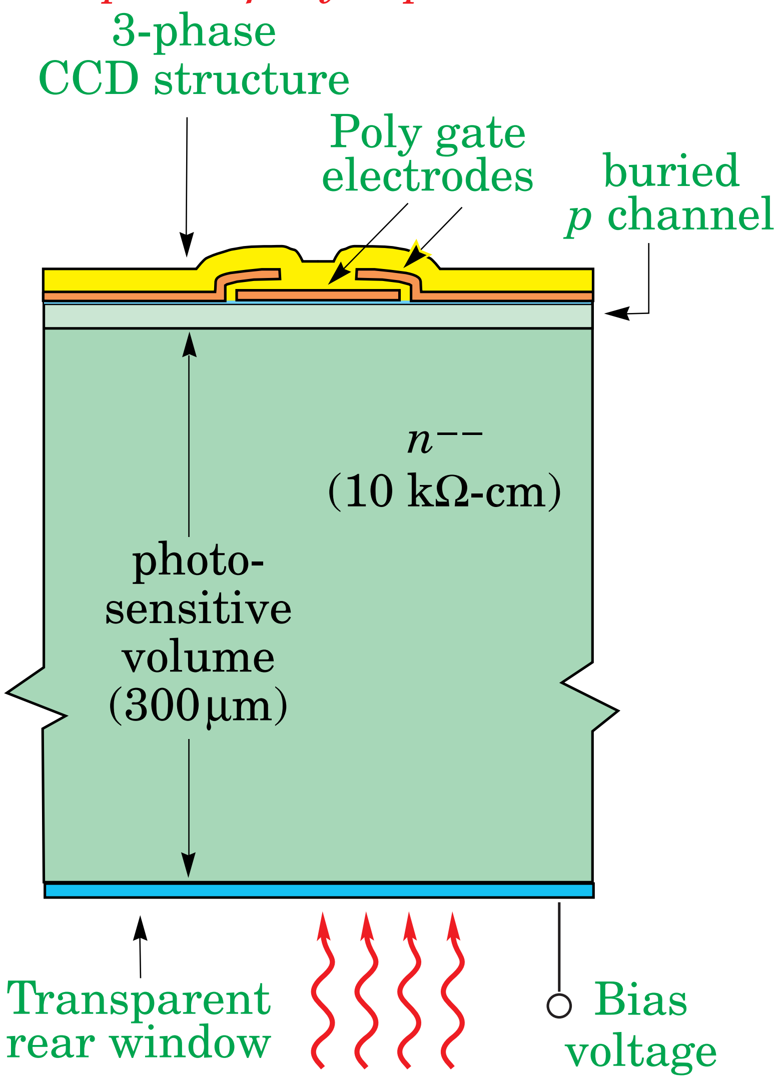


BaBAR Silicon Vertex Detector (~1m^2 Si)



Fully-Depleted CCD's

The New Approach:
Make a thick CCD on a high-resistivity n-type substrate, to operate fully depleted with rear illumination.



Advantages:

1) Conventional MOS processes with no thinning => "inexpensive"
2) Full quantum efficiency to > 1 µm => no fringing
3) Good blue response with suitably designed rear contact
4) Radiation tolerant

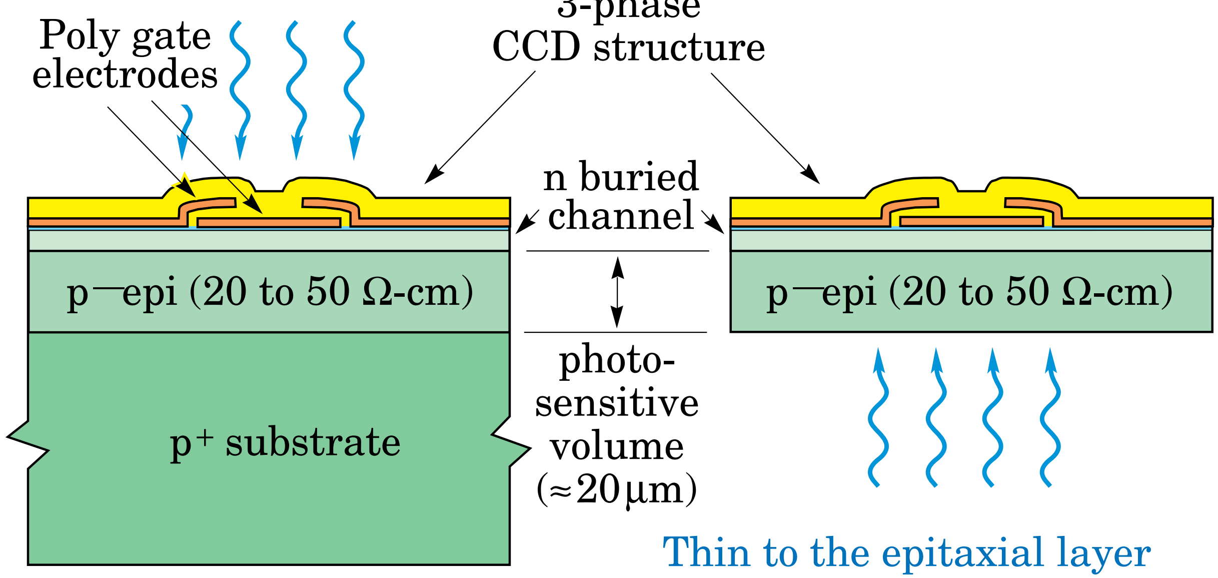
Disadvantages:

1) Enhanced sensitivity to radiation (x-rays, cosmic rays, radioactive decay)

Typical CCD’s

Front-illuminated CCD:

Thinned CCD with back-illumination:



Thin to the epitaxial layer thickness (≈20 μm)

Drawbacks:

1) Poor blue response due to absorption in polysilicon gate electrodes
2) Poor near-IR response due to thinness of the epitaxial layer
3) Interference patterns due to gate structure

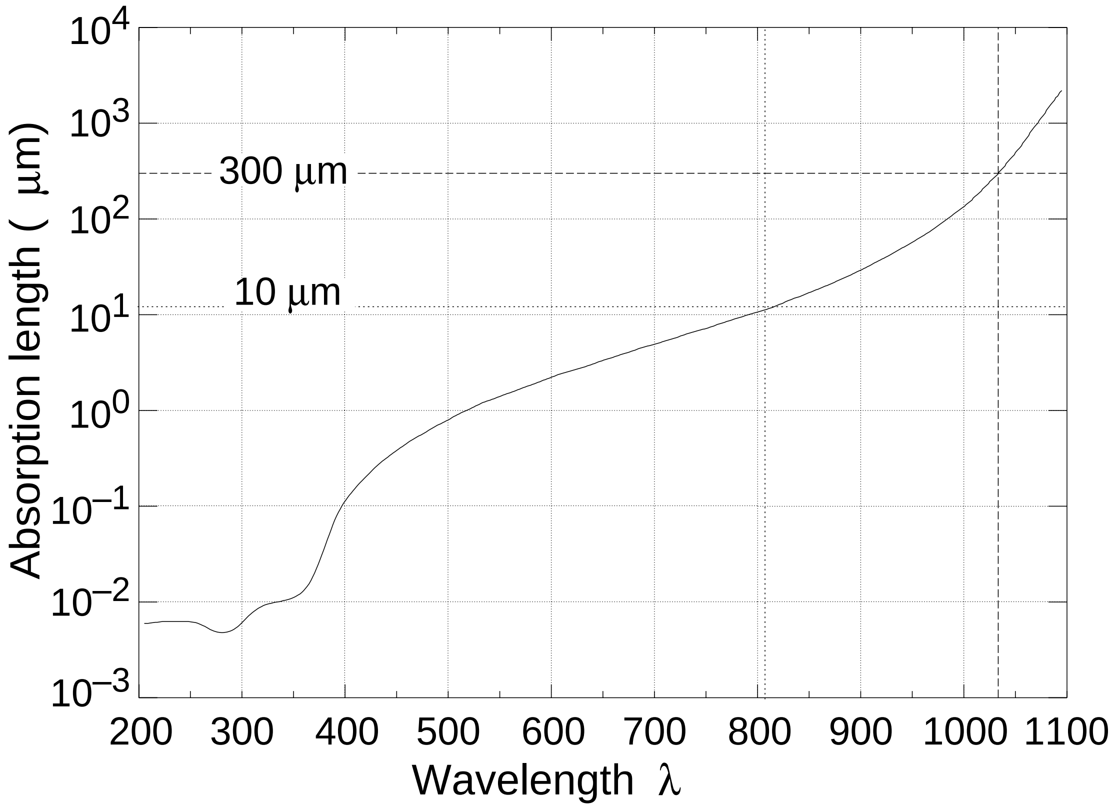
Drawbacks:

1) Thinning is difficult and expensive
2) Poor near-IR response
3) Interference (fringing)
4) Lateral diffusion in field-free region (degraded PSF)

CCD Technology

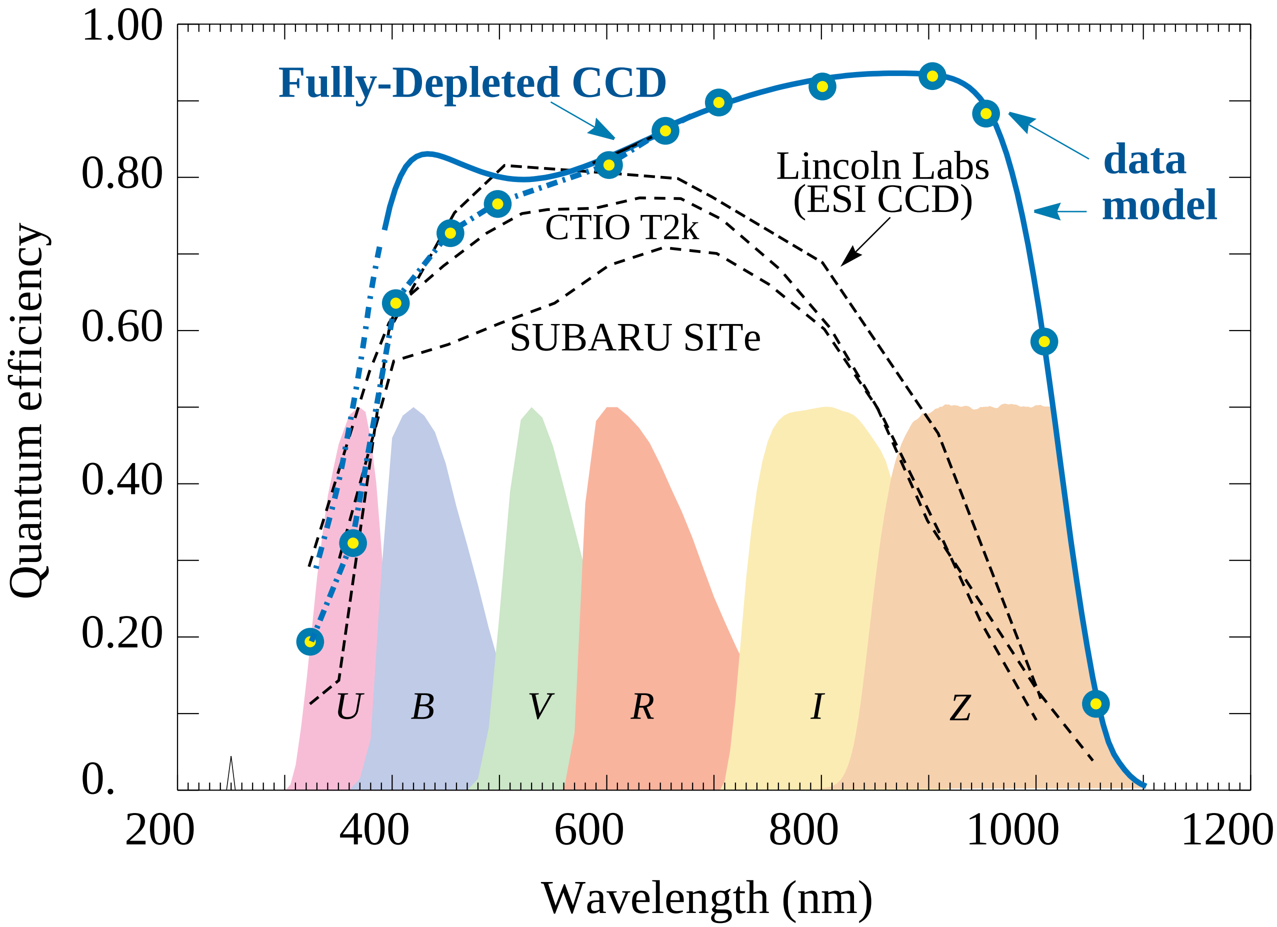
Photoactive region of standard CCD's are 10-20 microns thick

Photoactive region of Fully-Depleted CCD's are 300 microns thick

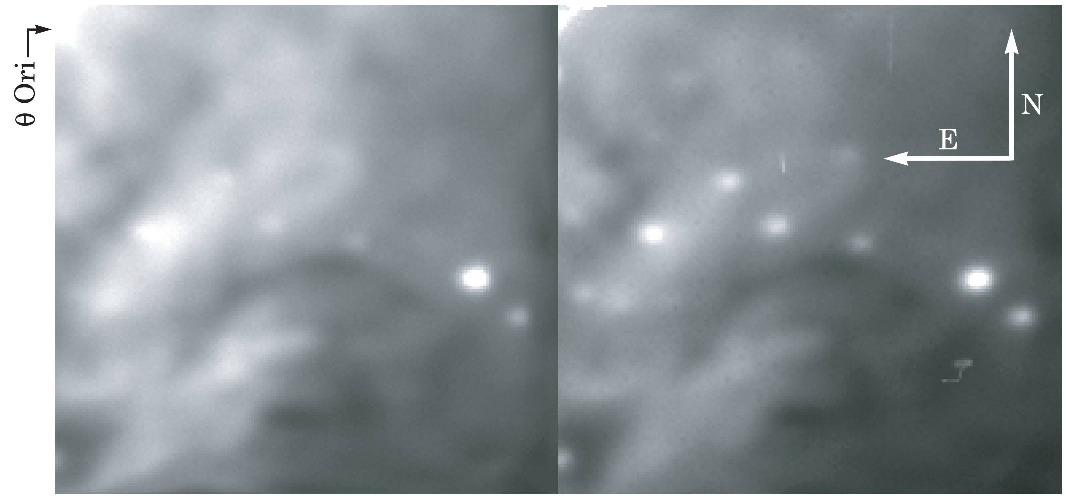


Quantum Efficiency

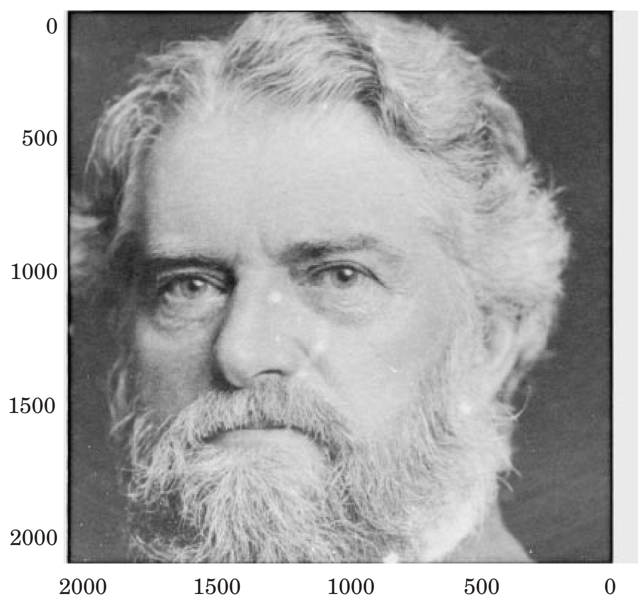
- Better overall response than more costly "thinned" devices in use
- High-purity silicon has better radiation tolerance for space applications
- Measured Quantum Efficiency at Lick Observatory (R. Stover):



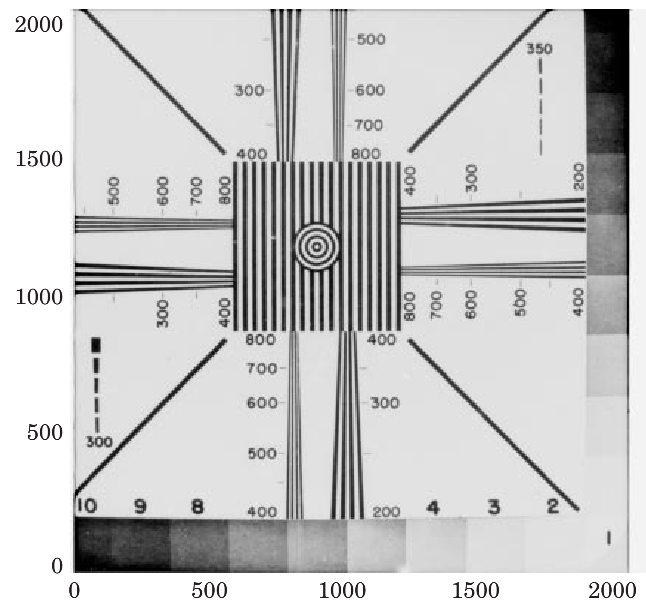
Portrait Gallery from Lick Observatory Fully-Depleted CCD’s



200x200
Lick Obs.
Orion
Left: R band
Rgt: Z band



2k x 2k

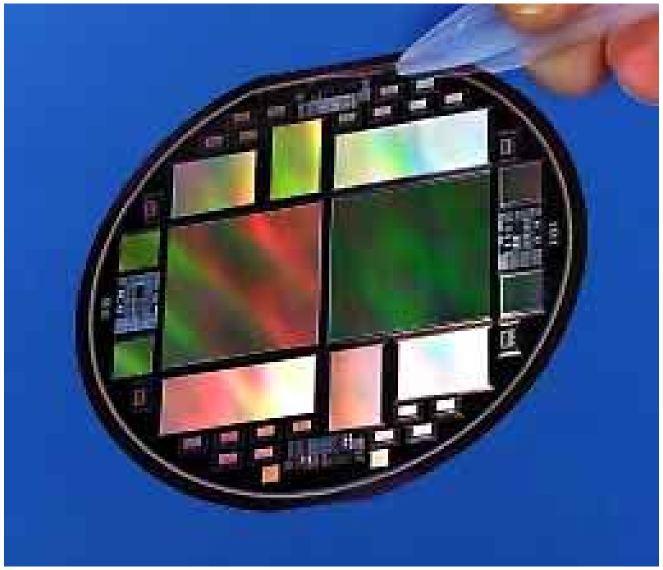


2k x 2k

CCD Status

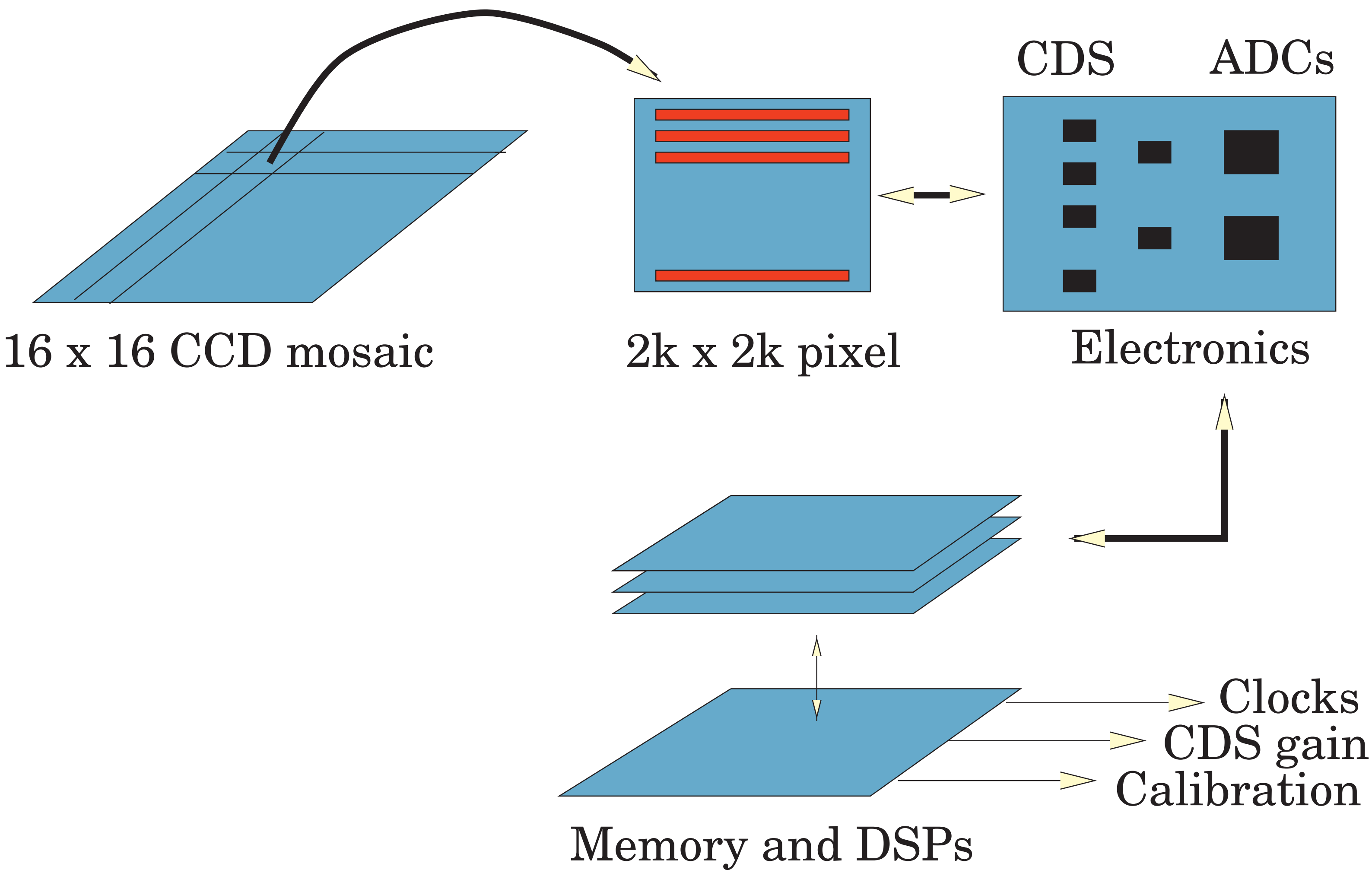
- 2k x 2k (15 µm pixels) design successful, meets SNAP performance requirements
- Commercialization at Mitel Corp, Bromont Canada
    - Fabricating 2k x 2k (15 µm pixels)
    - Two separate processing runs (1) Mitel “standard”; (2) modified process recipe
    - Current run of 25 wafers; will be followed immediately by another run
- Current in house fabrication
    - 2k x 4k (15 µm pixels) for Eschellette Spectrograph and Imager (Keck)
    - 2k x 4k (12 µm pixels)
    - 2k x 4k (10.5 µm pixels)

- NSF grant to develop technology for astronomy
- Requires further extensive radiation testing (already tested at LBNL 88” cyclotron to 20% of SNAP lifetime exposure w/o degradation) & large scale prototyping
- Complete commercialization



Electronics

GigaCAM Readout looks like high density vertex detector readout with 400 readout channels (two per CCD)



IR Photometry Requirements

Field-of-view	1’ x 1’
Plate Scale	1 pixel ~ 0.1 arcsec
Wavelength coverage	1000nm - 1700nm
Detector Type	HgCdTe (1.7 μm cut-off)
Detector Architecture	256 x 256 or larger
Detector Temperature	77K - 130K (to achieve dark I)
Read Noise	6 e- (multiple samples)
Dark Current	3 e-/min/pixel
Readout Time	20 sec
Limiting Magnitude	30th magnitude (AB)
Exposure control	Mechanical shutter
Filters	J&H, plus five special filters

3-channel Spectrograph Requirements

Optical:

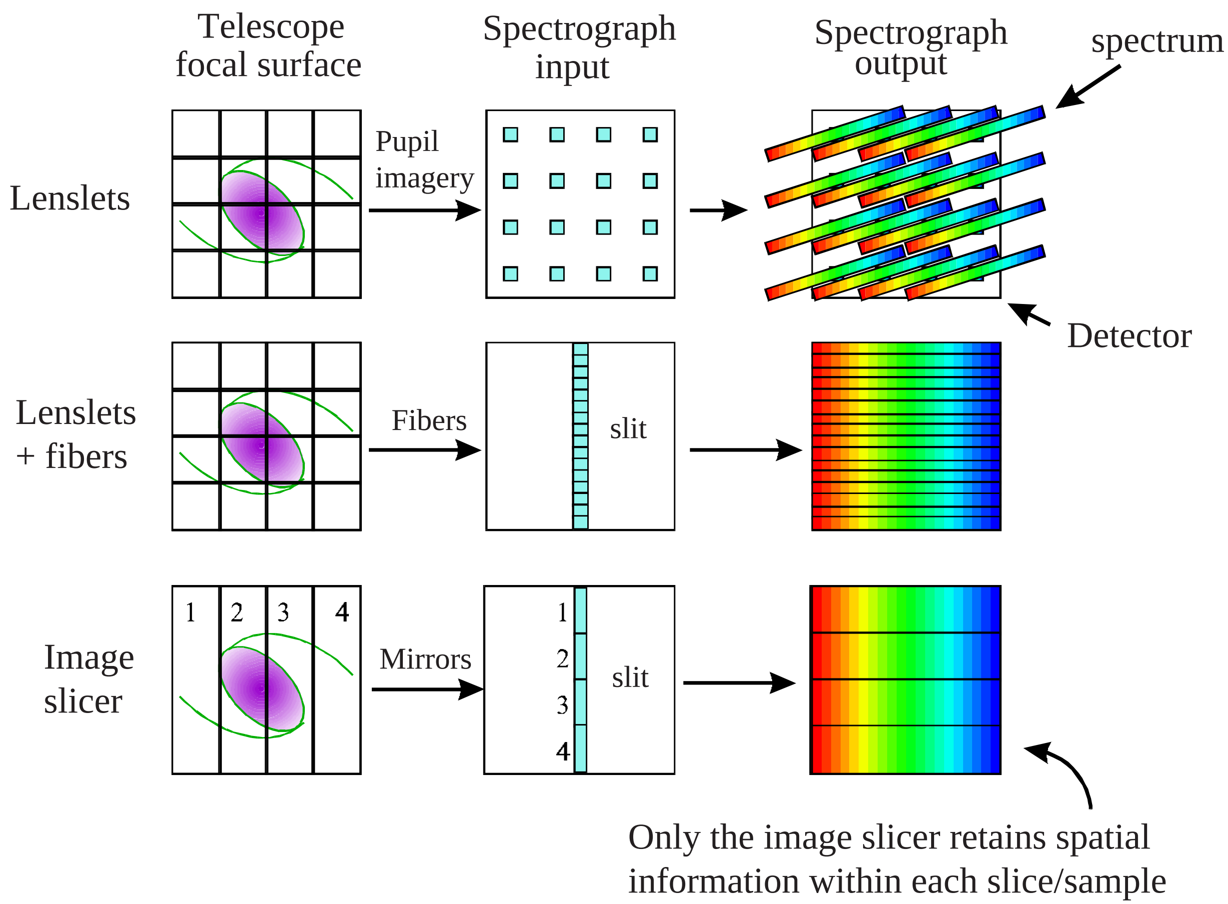
Spectrograph architecture	Integral field spectrograph, two channels
Wavelength coverage	350-600 nm, 550-1000nm
Spatial resolution of slicer	0.07 arcsec
Field-of-View	2” x 2”
Resolution	15A, 30A, 100A selectable
Detector Type	CCD
Detector Architecture	2k x 2k
Detector Array Temperature	150 K
Quantum Efficiency	65% 1000nm, 92% 900nm, >85% 400-800nm
Read Noise	≤ 4 e- @100kHz
Dark Current	0.08 e-/min/pixel

IR:

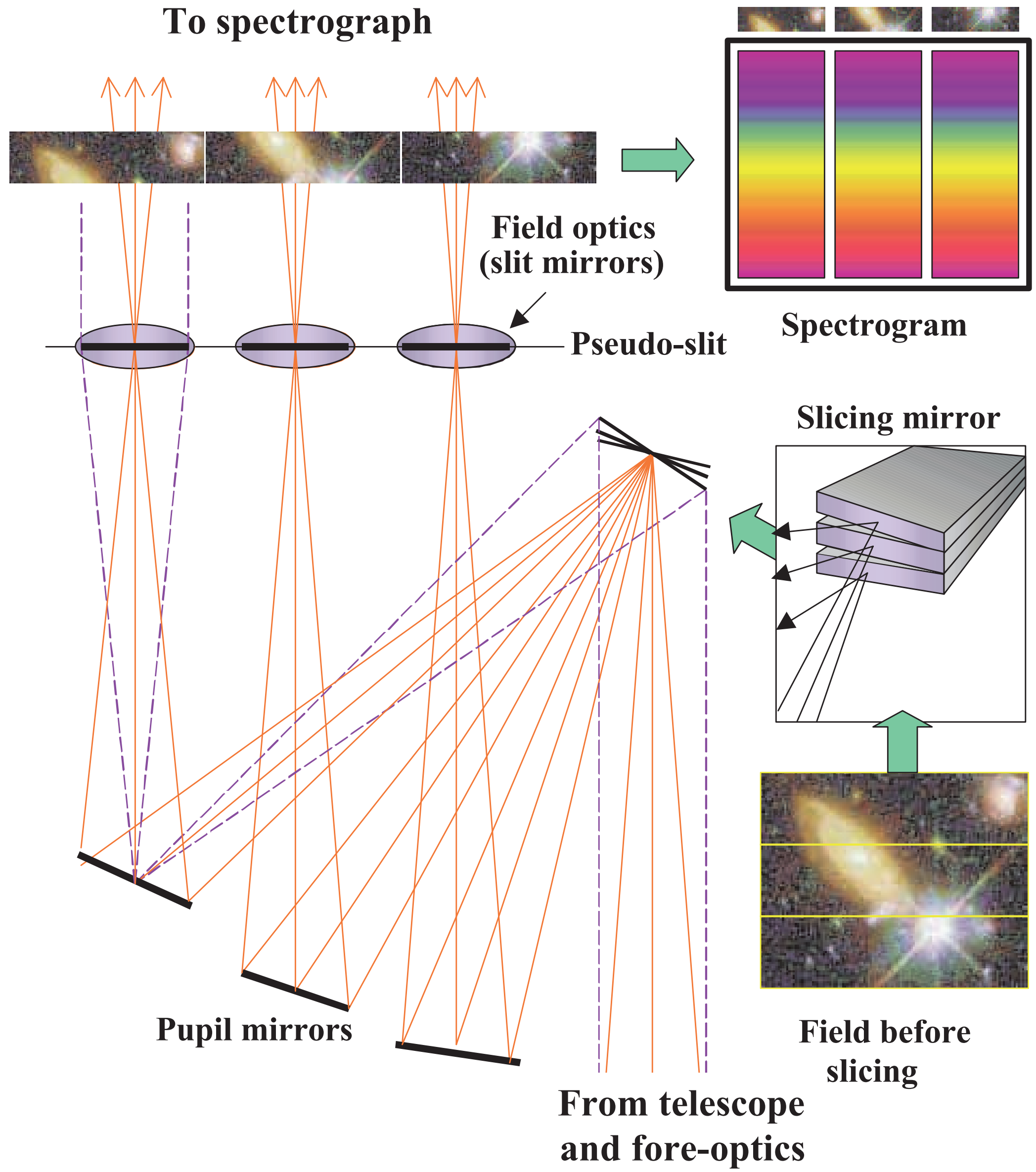
Spectrograph architecture	Integral field spectrograph, one channel
Wavelength coverage	900 to 1700 nm
Spatial resolution of slicer	0.12 arcsec
Field-of-View	2” x 2”
Resolution	30A, 50A, 200A selectable
Detector Type	HgCdTe
Detector Architecture	2k x 2k
Detector Array Temperature	77 - 130 K (to achieve dark I)
Quantum Efficiency	56% @ 1000nm
Read Noise	≤ 5 e- (multiple samples)
Dark Current	1 e-/min/pixel

Spectroscopy Technology

- MicroLens Array
- Reflective Image Slicer (e.g. Palomar 200", NGST IFMOS)



Integral Field Spectrograph for NGST



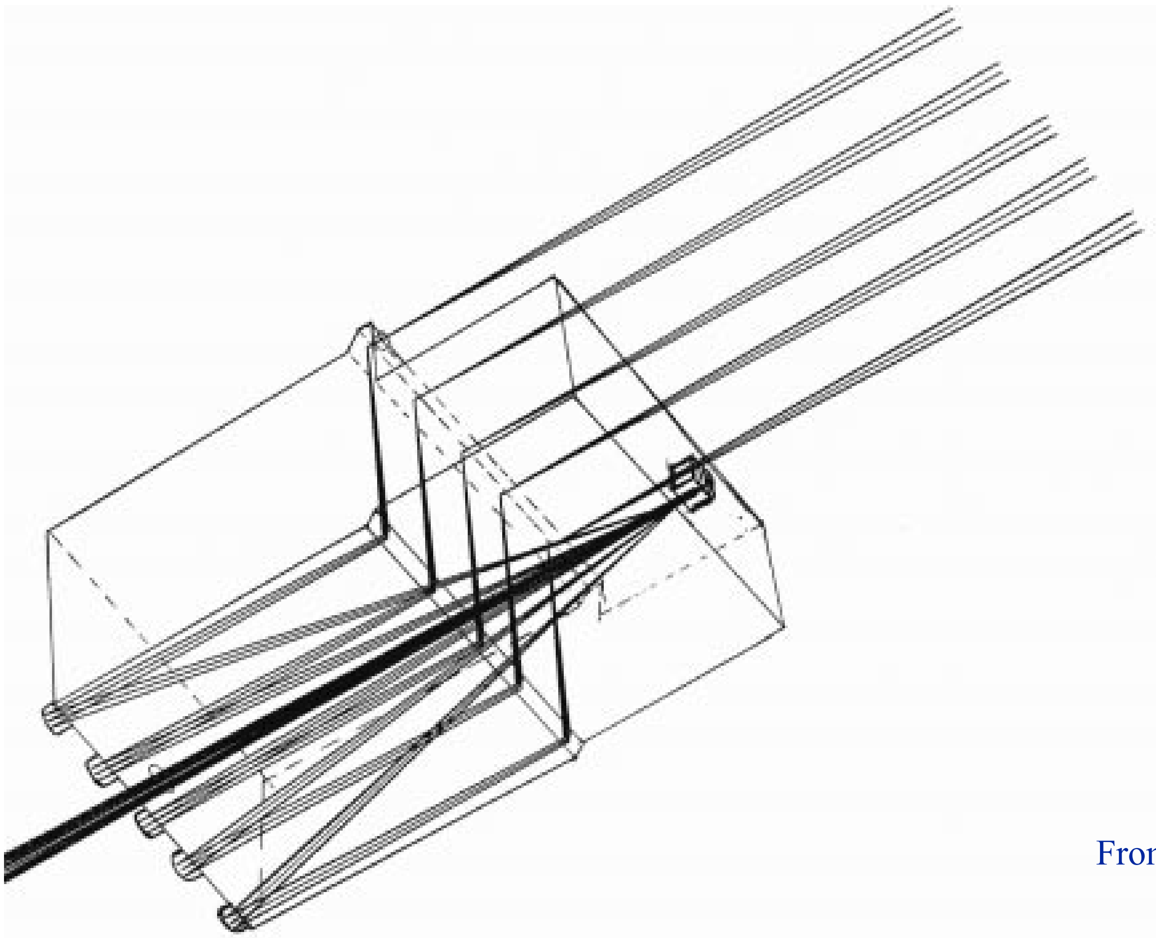
From LAS-NGST-IFMOS-004

O. Le Fevre, et.al - Laboratoire d'Astronomie Spatiale in Marseilles

Integral Field Spectrograph for NGST

Solid Block Image Slicer

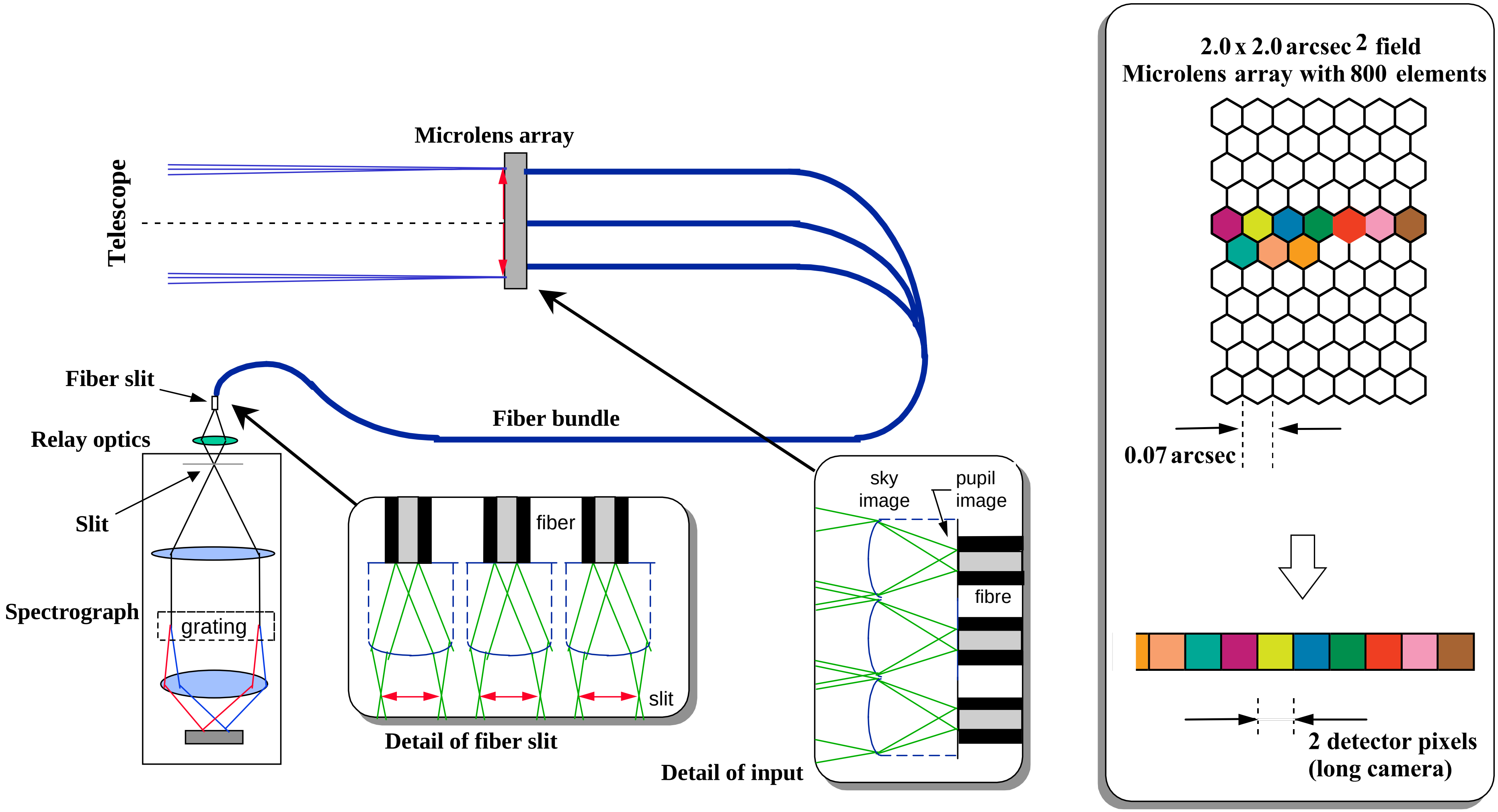
Very high throughput (90%)



From H. Richardson

Spectroscopy w/ fibers

MicroLens Array:



From Haynes, astro-ph/9909017

Observatory Requirements

Aperture	~2.0 meter
Field-of-view	1° x 1°
Optical resolution	diffraction-limited at 1 μm
Wavelength	350nm - 1700nm
Solar avoidance	70°
Temperature	~ 300 K
Fields of study	North and South Ecliptic Poles
Image Stabilization	Feedback from Focal Plane
Focal Length	20 meter

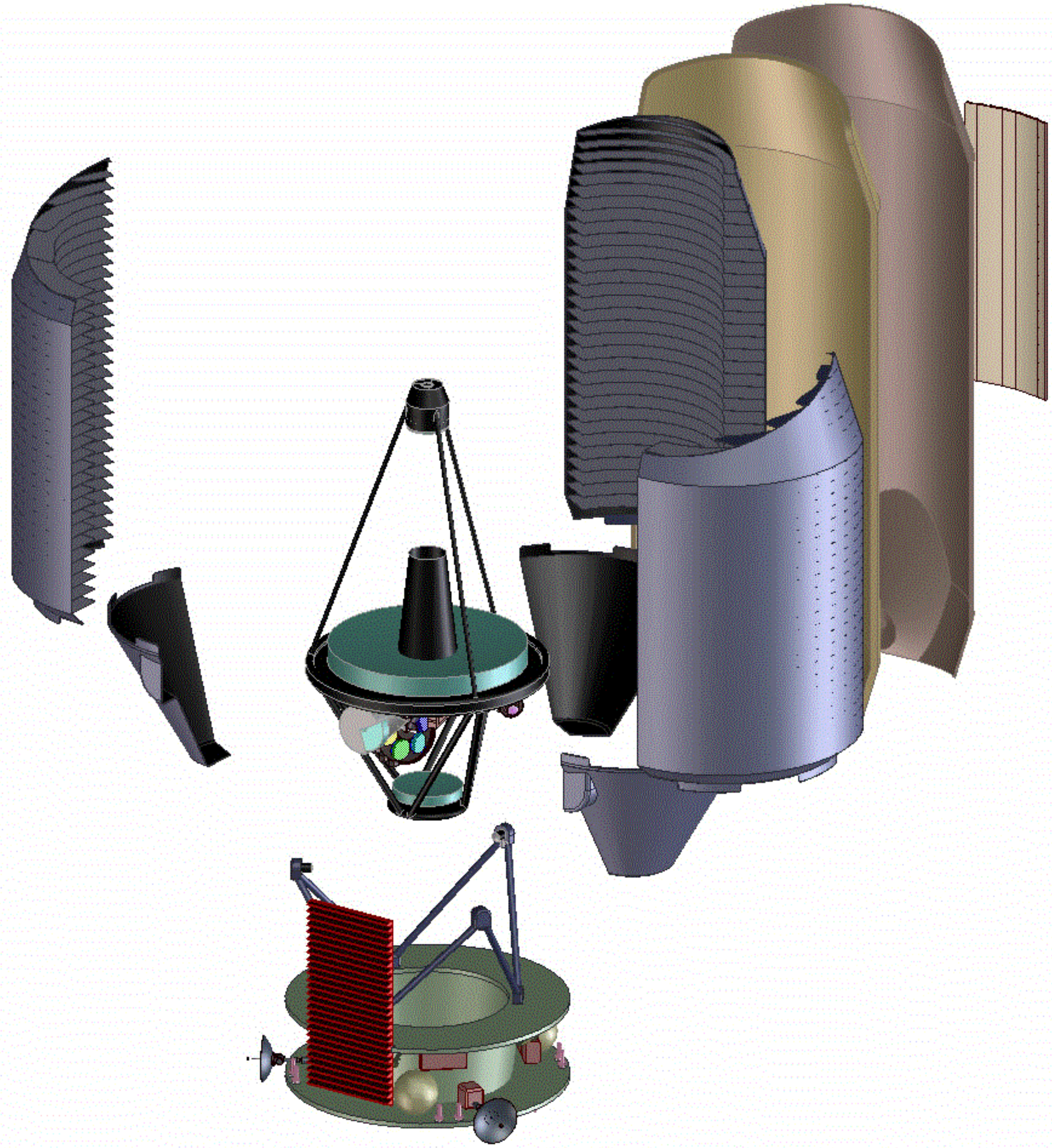
Spacecraft is always at near normal incidence to sun

Observatory

Simple Observatory consists of :

> **1) 3 mirror telescope w/ separable kinematic mount**
>
> **2) Optics Bench w/ instrument bay**
>
> **3) Baffled Sun Shade w/ body mounted solar panel and instrument radiator on opposing side**
>
> **4) Spacecraft bus supporting telemetry (multiple antennae), propulsion, instrument electronics, *etc***

No moving parts (ex. filter wheels, shutters), rigid simple structure.



Orbit

After trade studies concentrating on lunar assist " Prometheus" Orbit

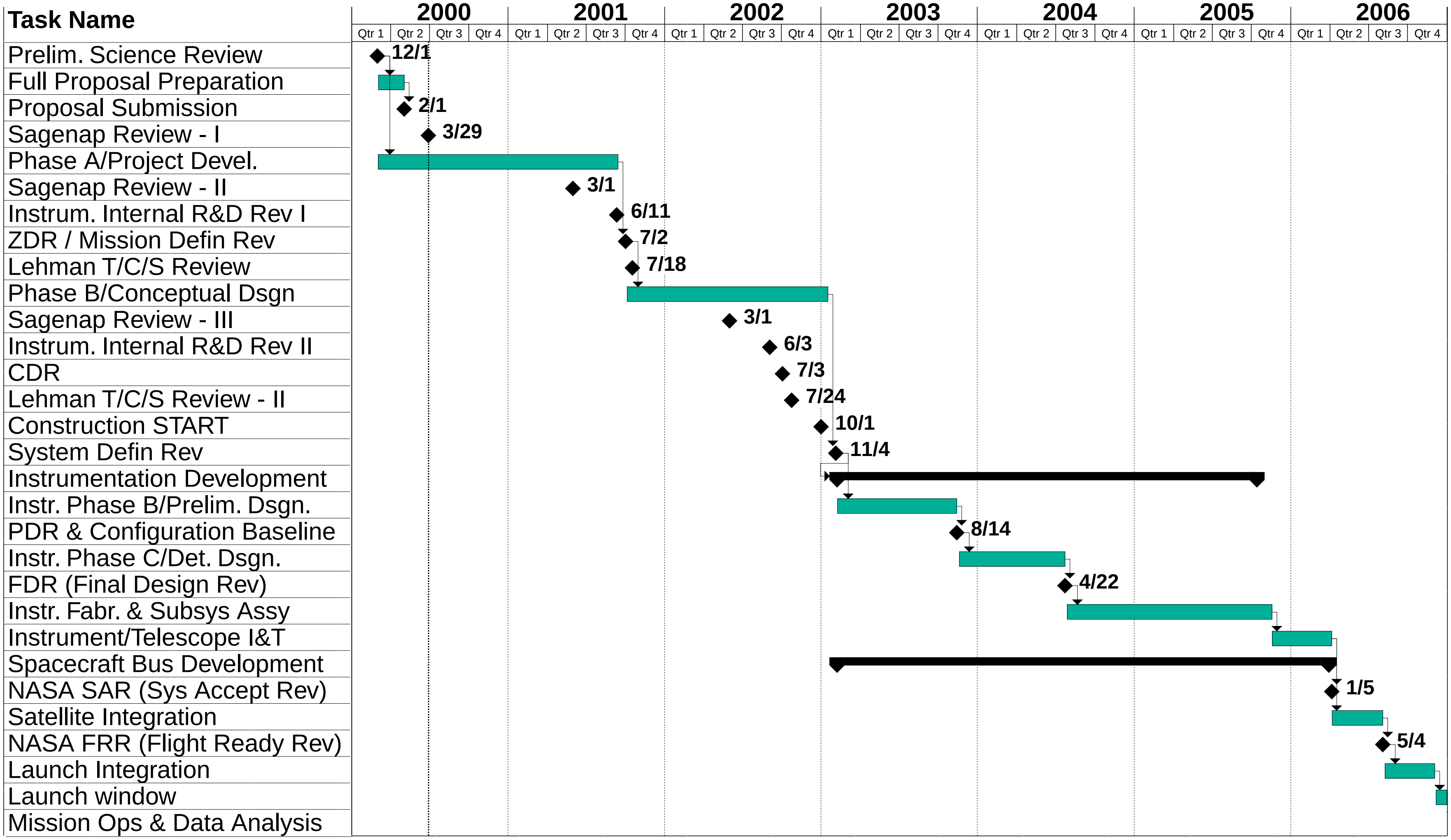
- Direct lunar insertion (two stage Delta IV), two mid-course corrections
- Lunar swingby to increase perigee above radiation belts
- High inclination (up to 70 degrees), high angle of perigee
- 7 day (8/40 Re) or 14 day (19/57 Re) period to avoid lunar perturbations
- Solves telemetry for high bandwidth images from optical imager

Spacecraft

In following talks:

- Collaboration capabilities in spacecraft
- Optical design
- Spacecraft properties
- Ground station
- Mission operations

Preliminary Schedule



Preliminary Schedule

Milestone / Task	Milestone or Start Date
Preliminary Science Review	Dec-99
Phase A Start	Dec-99
Proposal Submission	Feb-00
SAGENAP Review - I	Mar-00
SAGENAP Review - II	Mar-01
ZDR / Lehman T/C/S Review – I	Jul-01
NASA - Mission Definition Review	Jul-01
SAGENAP Review – III	Mar-02
CDR / Lehman T/C/S Review - II	Jul-02
Project START	Oct-02
NASA System Definition Review	Nov-02
PDR & Configuration Baseline	Aug-03
Final Design Review	Apr-04
Instrument/Telescope I&T	Aug-05
NASA System Acceptance Review	Jan-06
NASA Flight Readiness Review	May-06
Launch Integration	May-06
Launch Window	Sep-06
Mission Operations & Data Analysis	Oct-06

SNAP Interim Organizational Chart